



YOUR GUIDE TO

# Ground-Source Heat Pumps



## GROUND-SOURCE HEAT PUMPS: Four Reasons to Switch



Ground-source heat pumps run on electricity and use the constant temperature of the ground to provide heating and cooling for your home.

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Ground-Source Heat Pumps (GSHP)

# Technology Overview

**Ground-Source Heat Pumps** are heating and cooling systems that transfer heat between the earth and your home. Ground-source heat pumps operate similarly to a refrigerator, but on a much larger scale. A refrigerator moves heat out of the refrigerator or freezer to an outside coil, which is warm to the touch due to the heat it has extracted. The GSHP uses a more sophisticated version of the same technology to pump heat from the ground into the house during heating, and from the house into the ground when cooling.

Ground-source heat pumps do not burn fossil fuels; they use electricity to run a compressor. Because they take advantage of the stable, underground temperature of the earth (about 50 degrees Fahrenheit in Massachusetts), ground-source heat pumps are the most efficient heating and cooling system available. They are much more efficient than electric resistance (electric baseboard), oil, propane, or natural gas heating. They also provide highly efficient air conditioning.



Heat Pump



Loop Field

Most ground-source heat pump systems feature an underground loop of piping that circulates an anti-freeze fluid (a mixture of water and non-toxic propylene glycol or ethanol) between the ground and a central heat pump unit. The central heat pump is usually located in the basement or mechanical closet of a house. It includes a refrigerant loop with a compressor, reversing value, expansion valve, and two heat exchangers. One heat exchanger transfers heat between the outdoor fluid and the refrigerant. The second heat exchanger transfers heat between the refrigerant and the indoor distribution system, which brings the heating and cooling to all the rooms. The indoor distribution system may consist of ducts for forced air, hydronic baseboards, or radiant floors. In addition to heating and cooling, some ground-source heat pumps can also provide domestic hot water.

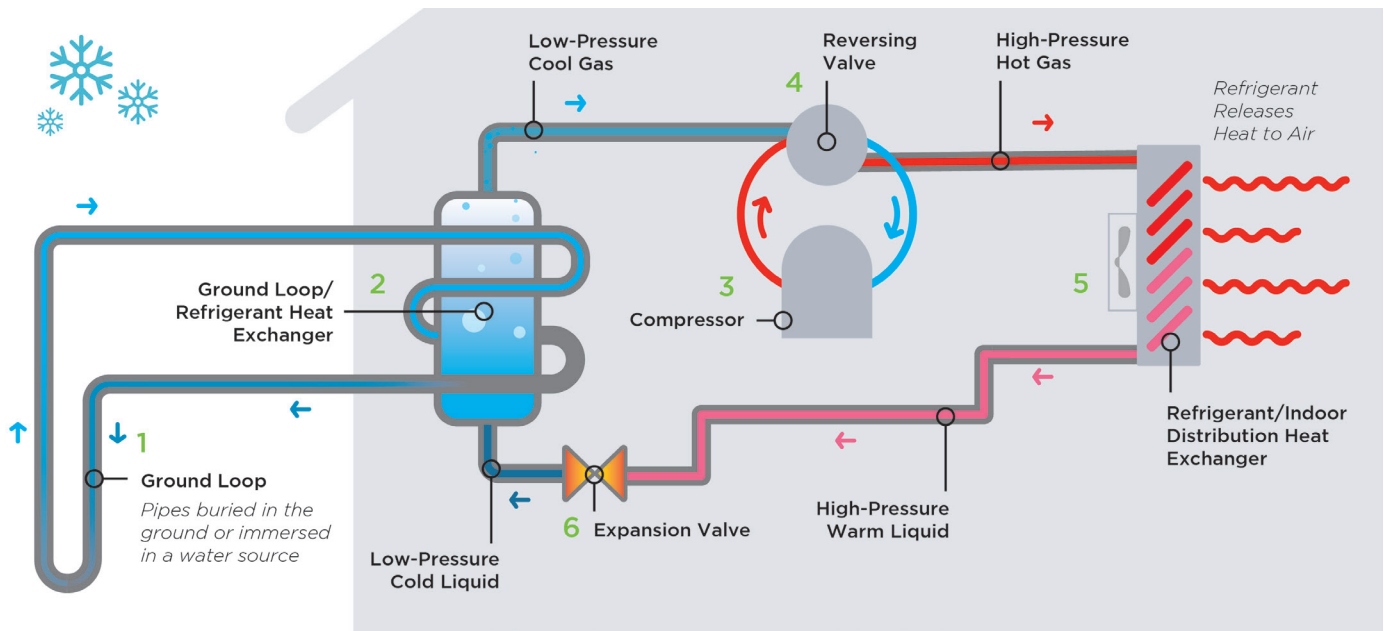


## GROUND-SOURCE HEAT PUMPS (GSHP)

# The Technology

### GSHP

#### Winter Mode



In the winter, anti-freeze fluid pumped through the ground loop absorbs low-grade heat from the ground (1). At the ground loop/refrigerant heat exchanger, the anti-freeze fluid transfers its heat to an indoor refrigerant loop, without any mixing of the two substances (2). The warmed refrigerant flows to the compressor where it is pressurized, causing it to heat up further (3). The reversing valve (4) directs the hot refrigerant to the refrigerant/indoor distribution heat exchanger, where the heat is transferred to the air- or water-based distribution system that spreads the heating throughout the house (5). The refrigerant next passes through an expansion device (6), which makes it very cold. Because it is now colder than the temperature of the anti-freeze fluid in the ground loop, the refrigerant can again absorb heat from the ground loop to begin the cycle again (2).

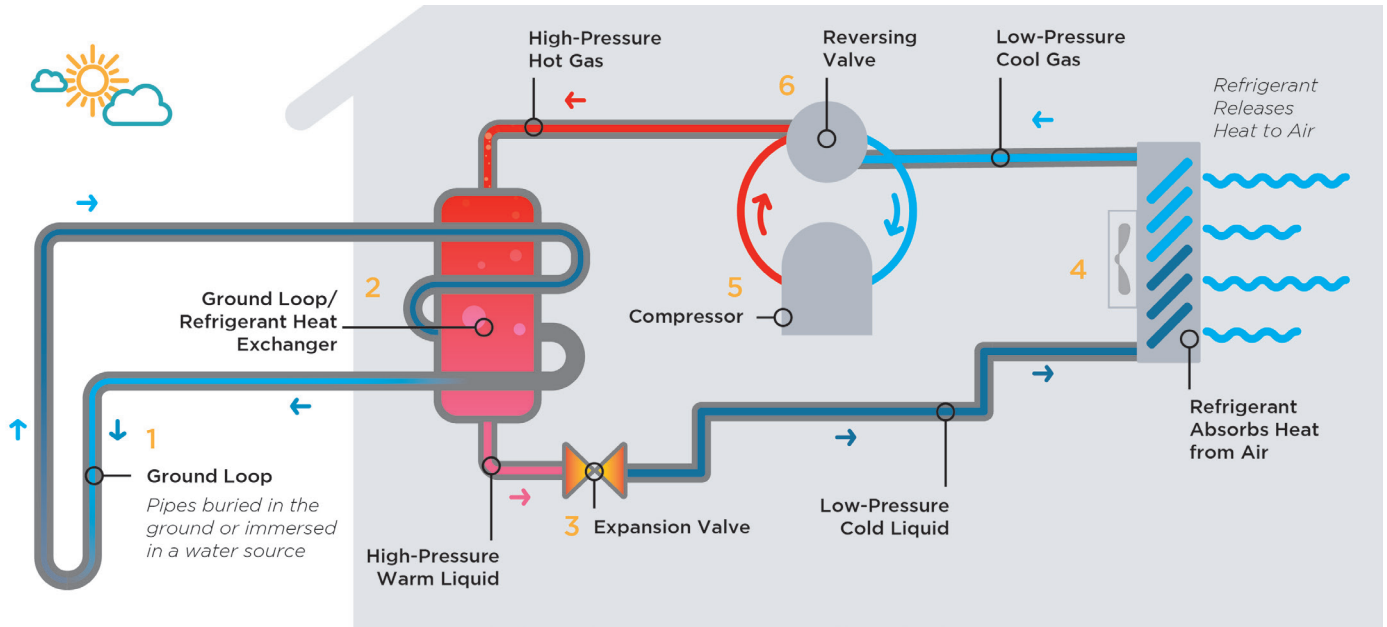


## GROUND-SOURCE HEAT PUMPS (GSHP)

# The Technology

### GSHP

#### Summer Mode



In the summer months, the process is reversed. Anti-freeze fluid from the ground loop (1) cools the refrigerant at the ground loop/refrigerant heat exchanger (2). The refrigerant then flows through the expansion valve (3), which makes it even colder. At the refrigerant/indoor distribution heat exchanger (4), this cold refrigerant absorbs heat from the air or hydronic distribution system, cooling the interior of the house. The compressor then concentrates the heat in the refrigerant (5), and the reversing valve (6) directs the hot refrigerant back to the ground loop/refrigerant heat exchanger (2), where the refrigerant easily releases the heat to the ground loop. The fluid in the ground loop is then cooled by the earth (1).

Ground-source heat pumps work very well in four-season climates like New England's. You are not limited to the temperature of the ground and you do not need a supplemental fossil fuel system to keep your house comfortable year-round.





## GROUND-SOURCE HEAT PUMPS (GSHP)

# The Technology

### GROUND-SOURCE HEAT PUMP CONFIGURATIONS

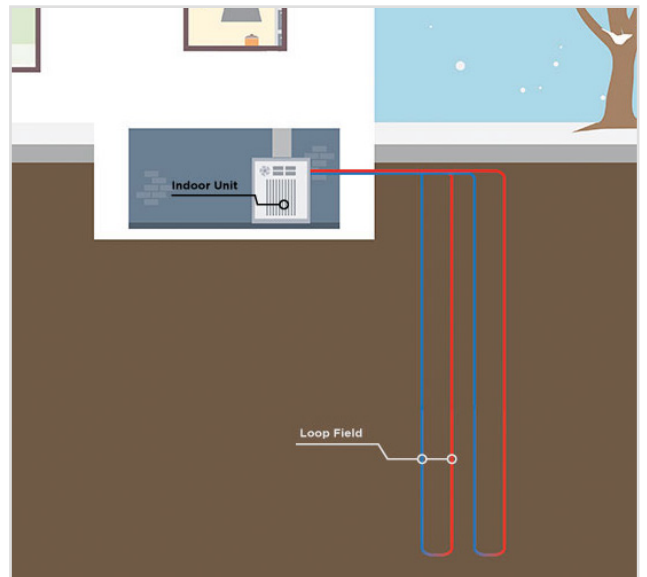
The ground loops for ground-source heat pump systems can be installed in different configurations, depending on the amount of land available and whether there is a pond next to a home. The most common system type in Massachusetts is a **closed-loop vertical system**. The system circulates an anti-freeze mixture through pipes that extend around 500 feet into the ground within one or more boreholes that are at least 20 feet apart from each other.

The second most common type of ground-source heat pump in Massachusetts is an **open loop system**. This system exchanges water directly with an underground well. Ground water is returned to the well after passing through the heat pump.

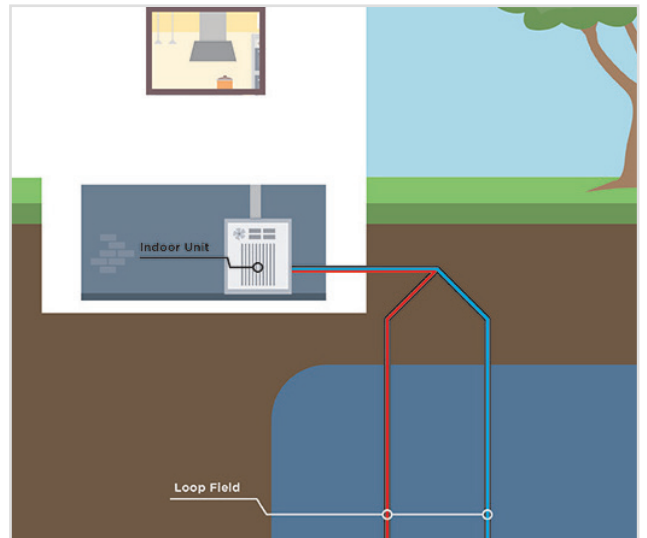
Another ground-source heat pump configuration that is less common in Massachusetts due to space requirements is called a **closed-loop horizontal system**. Similar to the closed-loop vertical system, an anti-freeze solution is circulated through pipes that are laid out horizontally at a depth of about six or more feet underground. Horizontal loop systems require more yard space than vertical loop systems. Horizontal loop systems can cost less to install if the digging conditions are favorable. Closed-loop horizontal systems can be less efficient than vertical systems, due to the greater ground temperature fluctuations at shallower depths.

### HOME IMPROVEMENT SCENARIOS THAT WORK WITH GROUND-SOURCE HEAT PUMPS:

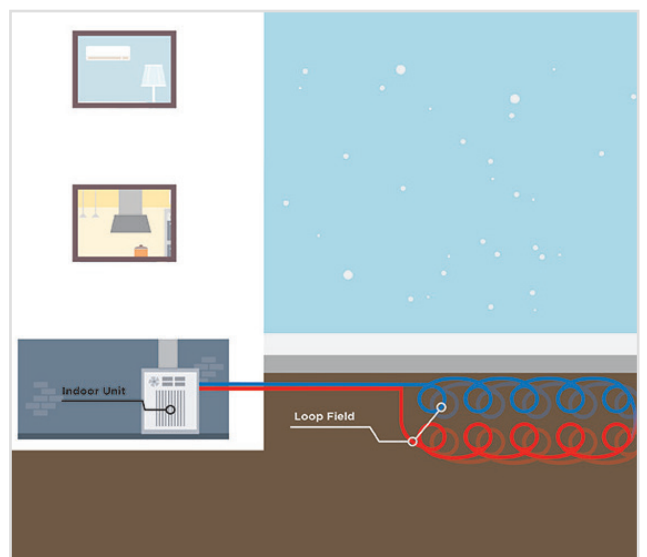
- Existing home replacing heating or cooling system
- Existing home doing major renovations
- New home construction using ductwork or baseboard heaters



Closed-Loop Vertical



Open-Loop Vertical



Closed-Loop Horizontal



## GROUND-SOURCE HEAT PUMPS (GSHP)

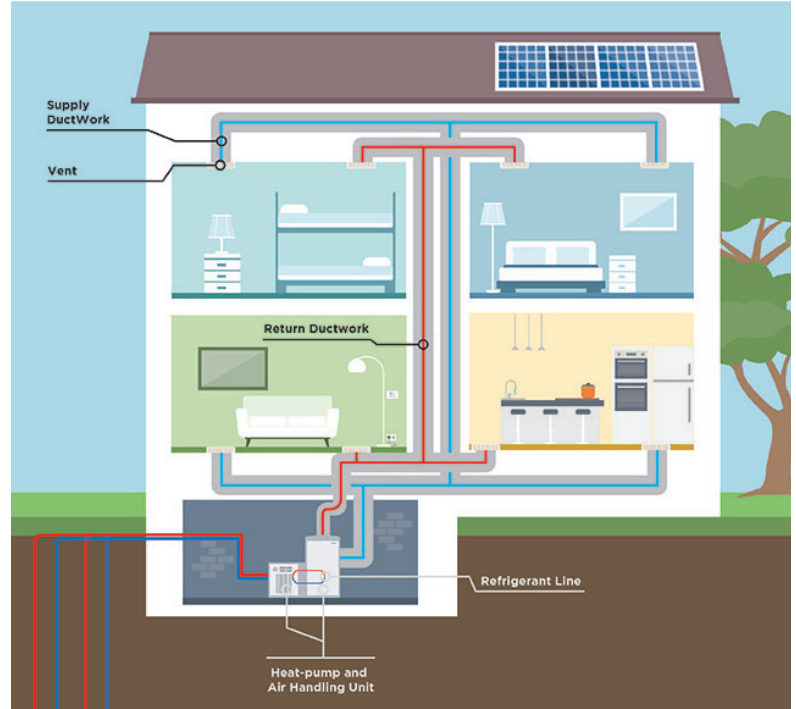
# Distribution System Types

Ground-source heat pumps can be paired with either forced hot air or hydronic distribution systems to distribute heating or cooling throughout the home. With **forced hot air distribution**, the heat pump transfers heat to air that circulates through ductwork. With **hydronic heating distribution**, the heat pump transfers the heat to water that is circulated to baseboards or radiators. One reason ground-source heat pump systems are so efficient is that they deliver water at modest temperatures, approximately 110 to 120 degrees Fahrenheit, but this usually requires longer baseboards or larger radiators than those designed to work with traditional boilers. However, the old baseboards or radiators can often be replaced by heat-pump-compatible ones in the same locations.

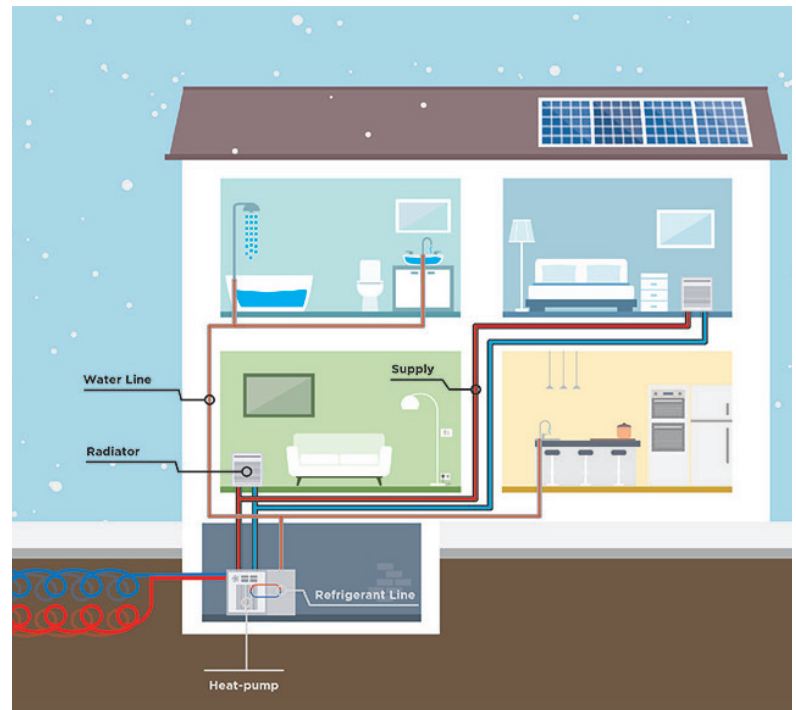
Ground-source heat pump systems are compatible with zoning your house for heating and cooling. Depending on the size of a home, multiple heat pump units may be used to heat sections of a house (such as an entire floor or all of the bedrooms).

### DISTRIBUTION SYSTEMS THAT PAIR WELL WITH GROUND-SOURCE HEAT PUMPS

- Forced-hot-air ductwork
- Baseboard radiators



Home with Ductwork



Home with Baseboard Radiators



## GROUND-SOURCE HEAT PUMPS (GSHP)

# Are Ground-Source Heat Pumps a Good Fit For My Home?

If you answer yes to ANY of the following questions, then GSHPs may be a good fit for your home.

☐ **Do you want to reduce your home's greenhouse gas emissions?**

GSHPs run on electricity instead of burning fossil fuels to heat and cool your home, reducing your home's greenhouse gas emissions.

☐ **Do you heat your home with oil, propane, or electric resistance?**

Ground-source heat pumps are the least expensive to operate of all the clean energy systems and the energy savings will be greatest.

☐ **Do you have a enough yard space?**

You don't need a huge yard to install a ground-source heat pump, but you will need enough room to fit a drill rig onto your property. Drill rigs are very large trucks; imagine a truck over sixteen feet long, six feet wide, and eight feet tall going into your front or back yard. Ground-source boreholes generally need to be at least 15 feet away from your home's foundation and spaced 20 feet apart. The number of bore holes needed depends on the size and heating needs of a home. A typical 2,000 square foot home would require 2 bore holes. After drilling is complete, homeowners can landscape over the borehole area (or over the loop field, in the case of a horizontal system).

☐ **Does your home have existing ductwork?**

GSHPs are easy to add to homes with existing ductwork, especially ductwork that is already sized to provide heating and cooling. Ground-source heat pumps can also use radiant floor heating or other hot water distribution if they are sized for low-temperature hot water. Other existing heating distribution systems (i.e., radiators and some hot water baseboards) may need to be retrofitted or replaced for compatibility with GSHPs. If you are installing new ductwork as part of your GSHP installation, the ductwork typically takes between 3 and 5 days to install.

☐ **Do you have photovoltaic (PV) solar panels on your roof?**

GSHPs operate using electricity. If you already have PV panels on your roof, then you can use your existing solar panels to run your heat pump, decreasing or even eliminating your operating expenses. Because GSHPs are the most efficient heating and cooling option, their electricity needs can be met with fewer PV panels.

☐ **Is your house weatherized (i.e., well-insulated and air-sealed)?**

Weatherized homes require less energy to heat, which will allow you to install a smaller GSHP system (less drilling!), reducing the cost of installing a GSHP system and lowering the operating cost.





## GROUND-SOURCE HEAT PUMPS (GSHP)

### Case Studies



*The new air-handling unit to provide heating and cooling in the Wheeler's home.*

Anastasia and Ezekiel Wheeler installed a ground-source heat pump system in 2019 to heat and cool their two-unit home and have been extremely pleased with the outcome. Before the installation, their 18th century home was heated by an oil burner with baseboard distribution. They have been enjoying the increased comfort from the ground-source heat pump.

"It's definitely quieter," Ezekiel stated, "The system circulates the air around which is nice as the air is a bit fresher, less stagnant, especially when you wake up in the morning. The house is a little drier".

As part of the installation, the Wheelers had ductwork installed in their antique home. Although this was a challenging aspect of the project, the end result was excellent. Ezekiel calculated a break even point of 12-17 years for replacing his oil heat with a ground-source heat pump. This includes the cost of installing ductwork, which was one third of the project cost.

In addition to their heat pump, the Wheelers also installed solar PV on their roof and purchased an electric car, in their quest to become a fossil-fuel free household. Ezekiel is very motivated to reduce his impact on the planet and feels that "a sustainable future needs to be profitable, more fun and more comfortable, or there's no chance of it getting done." He is pleased to report "so far, so good" on all those fronts.

**"A sustainable future needs to be profitable, more fun and more comfortable, or there's no chance of it getting done." – says Ezekiel.**



## GROUND-SOURCE HEAT PUMPS (GSHP)

# Case Studies

Achieve Renewable Energy Systems, LLC installed a ground-source heat pump system in a 2,890 square foot home in Winchester, Massachusetts. The house consists of the original home, constructed in 1937, and an addition, constructed in 2005. Prior to installing ground-source heat pumps, the house was heated by a fuel oil boiler supplying baseboards in the original home, and hydronic forced air in the addition; air-conditioning was installed only in the addition. The fuel oil use was very high with over 2,000 gallons consumed annually.

The homeowners primarily wanted to eliminate the use of fuel oil because of adverse health effects, but they were also interested in improving comfort, reducing operating costs, and reducing carbon emissions.



After conducting an energy audit that showed the house was poorly insulated and inefficient, Achieve increased insulation in the attics, walls, and basements prior to installation. The energy efficiency upgrades allowed Achieve to install a smaller system, lowering the project costs and operating expenses for the homeowners. The ground-source heat pump system consists of two heat pumps and two bore holes, each with a depth of 380 feet.

After the ground-source heat pump installation, fuel oil use was eliminated. The homeowners report a dramatic improvement in comfort, especially on cold days. This is a result of both the ground-source heat pump installation and the energy efficiency upgrades. The homeowners say that the ground-source heat pump is much quieter than their old heating system and the heating operating costs are noticeably lower. The homeowners averaged over \$300 per month in energy savings during 2019.



## GROUND-SOURCE HEAT PUMPS (GSHP)

# Benefits of GSHPs

### OPERATION

- Operating costs are typically lower than oil, propane, or electric resistance, and about the same as (or marginally higher than) natural gas heating
- Operates efficiently as a whole-building solution in cold climates, like Massachusetts

### FLEXIBILITY & FUNCTION

- Provides both heating, cooling, and potentially hot water in a single, efficient system
- Most efficient heating and cooling system available
- Can use ductwork that is already installed in homes

### COMFORT

- Consistent home temperature
- Compatible with zoned thermostats
- Quiet
- Safety
- No onsite fossil fuels

### GREENHOUSE GAS EMISSIONS

- Lower greenhouse gas impact than fossil fuels
- Potential to have zero greenhouse gas impacts when paired with solar PV or 100% renewable electricity







## GROUND-SOURCE HEAT PUMPS (GSHP)

### Cost

#### ESTIMATED COST

The cost to install a ground-source heat pump in your home will depend on the specific characteristics of the building, the extent to which you are replacing the existing distribution system, the kind of system you choose, and your installer. Costs also depend on the drilling/trenching required and the level of modification needed to your existing heating and cooling distribution system. Generally, prices will range from \$35,000 and up before the incentives are applied.

Homes that have less than 200-amp electrical service will incur additional costs for upgrading the electrical service to accommodate a ground-source heat pump system. You will also need to repair some landscaping after the drilling or trenching is complete. Keep in mind that heating operating costs (your monthly electric bill) for ground-source heat pumps tend to be substantially lower than the cost of oil or propane and about the same as natural gas. In the summer, electricity consumption by ground-source heat pumps is substantially lower than electricity consumption by traditional air conditioning systems. Ground-source heat pumps also require little to no maintenance and can last much longer than even their air-source counterparts.

Factors other than the upfront costs, such as increased comfort, greenhouse gas savings, and other benefits, should also be considered when evaluating a ground-source heat pump system. If your existing heating system is more than 10 years old, plan to replace it before it fails. The true cost to install a ground-source heat pump system is the difference between the full cost of installing a ground-source heat pump system compared with what you would have spent on a new boiler or furnace PLUS the cost of a central air conditioning system, since the GSHP provides both heating and cooling.

#### INCENTIVES

Incentives are available to homeowners in Massachusetts wishing to upgrade their heating and cooling system to a ground-source heat pump. Incentives depend on the kind of system installed, the system size, and your electric provider.





## GROUND-SOURCE HEAT PUMPS (GSHP)

# Incentives & Financing

### INCENTIVES

- **Mass Save® Electric Heating and Cooling Rebate:** If you are located in Mass Save® territory, you may be eligible for \$2,000 per ton of cooling capacity if you currently have oil or propane heat. Typical whole-home systems range from 3-5 tons of capacity.
- **Federal Investment Tax Credit:** For systems installed through 2022, 26% of the installed cost of the system may be claimed as a tax credit on your personal income tax return. The amount decreases to 22% in 2023 and is eliminated in 2024. See the [IRS website](#) and/or consult your tax advisor to confirm eligibility. Note that the Internal Revenue Service refers to ground-source heat pumps as heat pumps.
- **Massachusetts Sales Tax Exemption:** Ground-source heat pump systems are exempt from the 6.25% Massachusetts sales tax.
- **Massachusetts Alternative Energy Certificates (AECs):** AECs (worth approximately \$3-12 each) are provided to homeowners who install qualified ground-source heat pumps, depending on the square footage of the home and the level of home efficiency. Homeowners apply for AEC credits after installation. A typical 2,000 square foot home system could receive around 300 AECs worth approximately \$900-\$3,600. See the [Department of Energy Resources \(DOER\) website](#) for more information on AECs. \*Please note that the price of AEC credits is subject to market demand and that the price listed here may be different than the current market price.

### FINANCING

- **Mass Save® HEAT Loan:** If you are located in Mass Save® territory, then eligible ground-source heat pumps can be financed through the Mass Save® HEAT Loan, which offers loans of up to \$25,000 at 0% interest over terms of up to 7 years. If you are unsure whether you are eligible for Mass Save® incentives, check on the [Mass Save® website](#).
- If you are not eligible for Mass Save® incentives, check with your local municipal electricity provider to see if they have any financing options available for clean energy systems.





## GROUND-SOURCE HEAT PUMPS (GSHP)

# Efficiency First



Taking steps to air-seal and insulate your home will ensure that it is ready for your new ground-source heat pump system and will help reduce overall energy consumption. A tighter, more insulated home will not only save you money on operating costs and reduce your carbon emissions throughout the year, it may also allow you to buy smaller, less expensive equipment in the first place.

### There are a few ways to increase your home's efficiency and reduce its heating and cooling load.

- **Air sealing:** Ensuring there are as few gaps as possible for indoor air to escape and outdoor air to get in reduces the heating and cooling load in a home. Air leakage can represent up to 40% of space-conditioning costs in a leaky building. Weatherization professionals will focus on sealing leaks hidden in the attic, garage, or between floors. Air sealing often involves re-sealing windows, replacing broken or jammed vents, and replacing the rubber seals around door frames. Experienced professionals will know the common culprits of air leakage to target, but a professional assessment of hidden leaks using a blower door to pressure-test the house is the best way to find leaks in your house.
- **Insulation:** Working with a professional contractor to improve roof and wall insulation can considerably lower heat transfer, improving your home's efficiency. Many insulation contractors are trained to air seal before insulating, when it's much easier to do.
- **Duct Upgrades:** If your home utilizes a centralized heating or cooling unit with ducts outside of the conditioned space of the home (i.e., in an attic, basement, garage, or crawlspace), sealing and insulating the ducts can significantly improve the overall efficiency of your system by ensuring that more of the heated or cooled air gets delivered to where it is needed.

**Mass Save®** or your gas or electricity provider may provide a no-cost assessment to identify efficiency opportunities for your home and incentives to help pay for the upfront cost of insulating and air-sealing.





## GROUND-SOURCE HEAT PUMPS (GSHP)

# Making the Switch



1. **Confirm that ground-source heat pumps are the best fit for your home and your home energy priorities.**
2. **Understand the costs and plan how you will finance the project.** Check out the [Cost](#) and [Incentives & Financing](#) sections to understand the typical costs to install ground-source heat pumps.
3. **Contact installers.** MassCEC recommends contacting at least three installers to learn more about installing ground-source heat pumps at your property. Visit our [Find an Installer Near You](#) page for a list. Referrals from family, friends, or neighbors is another great way to find an installer.
4. **Prepare your home.** If necessary, take preliminary measures to get your home ready for a new heating system, such as upgrading your electrical service or completing any weatherization work recommended in your home energy assessment, like sealing air leaks or installing insulation. If you are planning to improve the weatherization of your home, make sure your installer is aware so that they take the reduced heating and cooling needs of your home into account when designing your ground-source heat pump system.
5. **Install ground-source heat pumps.** Talk to your installer about how long installation will take. Ground-source heat pump Installations typically take between 2 to 4 weeks, depending on home size, system complexity, and schedules of the driller and installer.



## GROUND-SOURCE HEAT PUMPS (GSHP)

# How Can I Prepare for a Ground-Source Heat Pump Installation?

### Does your home have adequate electrical service for a GSHP system?

How many amps of electrical service does your home have? If your home has less than 200 amp electrical service, talk to a GSHP installer about whether you may need to upgrade your electrical service to accommodate a GSHP system. Check out [this site](#) for instructions on how to determine the amperage of your home's electric service. [This Old House](#) also has a helpful video that shows what an electrician will do to upgrade your electric meter and panel. Upgrading your home's electrical service is a good investment if you might install an electric vehicle charger or other new electrical appliances in the future. This upgrade typically takes one day to complete, and usually cost around \$2,000 to \$3,000, which may include fees and permitting from your local permitting agency. This upgrade requires a licensed electrician who will coordinate with your electric utility and your local permitting agency.

### Locate property plans and share them with an installer.

Many towns have codes regarding how close the GSHP wells can be to your septic system, existing drinking water wells, and the property line. If you have a plot plan or blueprints of your property, share them with your installer so they can make sure that your yard has adequate space for a drill rig or a horizontal GSHP system that complies with all local regulations and codes.

### Delay new landscaping until after your GSHP is installed.

The installation of a GSHP system will disrupt your yard, whether you are drilling bore holes for a vertical loop or excavating for a horizontal loop. Grass, plantings, and walkways may be affected. The yard will need to be refinished after the holes are dug, so it is best to save major landscaping projects until after GSHP installation. Once the ground loops are installed you can landscape, pave, or place a patio directly over the drill site!

### Weatherize your home!

It's important to weatherize your home before installing a GSHP system. GSHPs operate best in well-insulated and air-sealed homes with efficient windows. Get a home energy assessment and implement the recommended weatherization measures. Make sure to tell your installer about any weatherization measures that you have done or are planning, so that they can size your GSHP system appropriately.





## GROUND-SOURCE HEAT PUMPS (GSHP)

# Questions to Ask Your Installer



During your conversation with installers, consider asking the following questions:

### CONFIGURATION

**Did you perform a heat load calculation to determine the sizing of the system?**

Many installers size systems using general rules and their experience. If you are installing a ground-source heat pump, it is important that the system is well designed, and a heat load calculation for your specific home is an important tool in selecting the right equipment.

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**What loop type system do you recommend and why?**

Make sure you understand what type of loop system (closed or open loop and vertical or horizontal loop) your installer recommends and how much of your yard will need to be re-done after the installation is complete.

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### COST

**What is the installation price and what incentives may be available? Who will apply for these incentives?**

Make sure that you understand upfront who will apply for any incentives that you are pursuing and when you need to apply for these incentives (before or after installation).

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# QUESTIONS TO ASK YOUR INSTALLER (CONT.)

**Aside from annual fuel or electricity costs, what other annual costs can I expect (such as regular maintenance or parts)?**

MassCEC suggests that you have your heat pumps inspected every one to two years. Ask if your contractor performs routine maintenance or if they have someone that they recommend.

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## TIMING

**How far in advance can we plan the installation and how long does the installation take?**

Be sure to communicate if you have particular time constraints and get a sense when your installer will be available to do the installation. Summer is the busiest time of the year for ground-source heat pump installers and many installers have some delays during the summer season.

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**What should I do to prepare for the installation?**

Make sure you understand from your installer if there is anything you need to do to prepare to have them working in your home and yard.

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## QUALITY ASSURANCE

**Do you provide a service agreement and/or warranty for the systems you install? What are the different options?**

Make sure you understand what is covered by any service agreement or warranty offered by your contractor. Some warranties cover labor, some cover the equipment, and some cover both.

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# QUESTIONS TO ASK YOUR INSTALLER (CONT.)

**Have you participated in manufacturer training for the systems you would install, and can you provide references from previous customers?**

As with any home improvement project, it is important to ensure that your installer has the right training and a good track record with past customers.

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**Will you hire subcontractors to complete portions of the project? If so, what will they do? What are the names of these companies and how long have you worked with them?**

Many ground-source heat pumps installers sub-contract the electrical work. Some will even allow the homeowner to select their own electrician.

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**Will you provide training for me on how to properly operate and maintain the system (i.e., how to set the thermostat)?**

Ground-source heat pumps are relatively simple to operate, but there are a few differences compared to other heating systems, and your installer should be a good educational resource.

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## GROUND-SOURCE HEAT PUMPS (GSHP)

# Getting the Most From Your New System



### OPERATION

- Ground-source heat pumps work most efficiently when you set your thermostat at a comfortable consistent temperature even when at work or away for the weekend.

### PROFESSIONAL MAINTENANCE

- Schedule an annual to bi-annual maintenance check with your ground-source heat pump installer to make sure that everything is running smoothly.





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